OIL AND GAS IN WESTERN CANADA

Energy, Mines and Resources Canada

Énergie, Mines et Ressources Canada

Canada

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Oil and gas are the keys to our modern way of life. Without oil and gas, there would be no vehicle fuels, synthetic fabrics, or modern drugs and chemicals. Imagine what life would be like without cars, buses and airplanes; without modern medicines; without plastics, paints, detergents and cosmetics.

Every day, we use the products of Canada's oil and gas industry. From simple beginnings, this industry has grown to be one of the largest and most sophisticated in the world. Today, the oil and gas industry employs more than 400 000 Canadians and is an important source of export earnings.

For many years, it seemed that Canada had a virtually endless supply of conventional oil and gas. However, these conventional supplies are steadily being depleted. Our oil and gas industry produces more than 90 million m^3 of oil (enough to fill 45 000 Olympic-size swimming pools) and 70 billion m^3 of gas annually. Nearly all of this is produced in western Canada.

Off shore and in the frontier regions of the Far North, new discoveries are helping to supplement reserves of conventional oil and gas. These discoveries, described in *Energy Under The Sea* and *The Northern Energy Search*, other publications in this series, are helping to secure our energy future.

But these conventional oil reserves are merely a fraction of the riches locked in the oil sands and heavy oil deposits of Alberta and Saskatchewan. There is more oil in these deposits than in all the oil fields of Saudi Arabia! However, getting it out of the ground and into a usable form is much more difficult. As Canada's reserves of conventional oil decline, the oil and gas industry is working harder than ever to find better ways to produce and process unconventional oils. This is no simple task as we'll see in later chapters.

We use the products of the oil and gas industry in virtually every aspect of our lives. (Imperial Oil Limited, R.M. Photography, Reddi-Chef, Shell Canada Limited)

But first, let's go back to the old days — before cars, before gas stoves, before permanent-press shirts and plastic cups. How did it all begin?

An Introduction to the Language of Oil and Gas

Several terms used throughout this booklet may need to be defined. The term *crude oil* refers to oil as it comes out of the well. Crude oil is a mixture of many different *hydrocarbons*, chemical compounds made up of carbon and hydrogen atoms.

***Heavy oil* is a viscous form of crude oil that usually requires pumping to bring it to the surface. *Bitumen* is a tarlike crude. Heavy oils and bitumen can be treated in various processes known, collectively, as *upgrading*, to produce *synthetic crude oil*, which resembles crude oil in appearance but has a modified chemical composition.**

How the industry began

Although the Canadian oil and gas industry is little more than a century old, historical evidence shows that North American Indians used oil in many ways, ranging from medicine to an ingredient in war paint.

It was not until the 1800s, however, that Canadians began to take oil seriously. In the 1850s, a Canadian geologist and chemist, Dr. Abraham Gesner, developed kerosene from coal. The clean new fuel rapidly replaced whale oil as the preferred source of lighting.

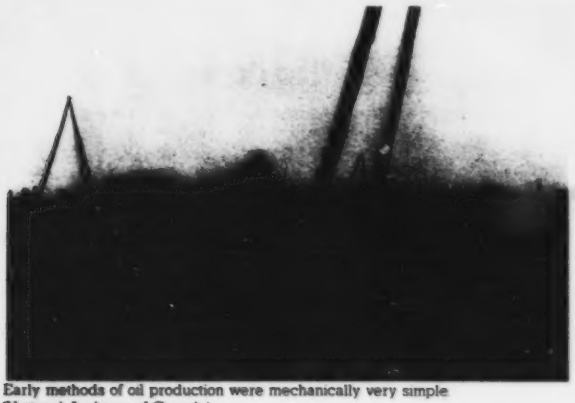
As the popularity of kerosene increased, entrepreneurs looked for other ways to produce it. The discovery that kerosene could be produced from crude oil marked the beginning of the petroleum era. Suddenly there was a reason to look for oil.

In 1858 a Canadian named James Miller Williams brought this growing interest in oil a step further by successfully producing oil from a well dug to a depth of almost 15 m. This well, located in Oil Springs, Ontario, became the first commercial oil well in the world. Williams's operation was actually North America's first integrated oil company, since it involved exploration, production, refining and marketing. This company eventually became the Canadian Oil Company in 1860.

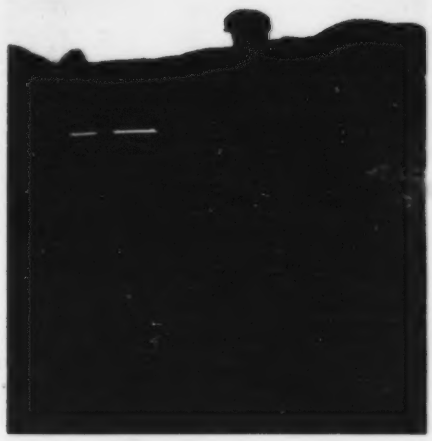
By 1863 about 30 refineries were operating in Ontario. To meet the growing demand for oil, the search moved west.

In 1883 Canadian Pacific Railway drillers seeking water accidentally found natural gas at Langevin near Medicine Hat, Alberta. By 1900 the supply of gas in Medicine Hat seemed so inexhaustible that streetlights lit by gas were left burning day and night. By 1909 gas in this area was being developed for commercial purposes.

Western Canada's first and biggest boom started when condensate (a very light oil) and natural gas were



Early methods of oil production were mechanically very simple
(National Archives of Canada)



The work of early geologists in mapping geological formations helped to pave the way for the modern oil and gas industry
(Imperial Oil Limited)

discovered at Turner Valley, Alberta in 1914. Calgary went wild as more than 500 companies were formed within a few months. But the boom was brief, because oil did not appear in the gushing volumes that companies had anticipated. At the time, oil companies saw little use for either condensate or natural gas.

Interest in Turner Valley slackened until 1936, when a geological structure revealed large reservoirs containing primarily crude oil, rather than gas and condensate. Turner Valley was confirmed as a large, genuine oil field and hundreds of wells were drilled.

Construction of the Turner Valley pipeline in the 1920s
(Glenbow Archives Calgary)

Production at Turner Valley peaked during World War II. Turner Valley remained Canada's only major oil field until the discovery in 1947 of the Leduc field southwest of Edmonton.

Geologists had no idea how fortunate the Leduc discovery would be. The field was located in Devonian rock formations. At the time, geological knowledge about rock formations in western Canada was limited, and only a few geologists believed that oil could be found in Devonian rock. Leduc proved they were right.

Further drilling in the Leduc area provided important information about Devonian reef formations. Many oil fields in these formations were subsequently discovered in several places between Calgary and Edmonton, and north to the Rainbow area. The Leduc discovery helped to usher in the modern age of Canada's oil and gas industry. With it, exploration and production became viable activities.

Major oil and gas discoveries were made throughout the Prairies during the late 1940s and 1950s as numerous companies joined the search. Between 1959 and 1964 major oil discoveries tapered off and the industry concentrated on developing reserves found since Leduc. The last major discovery of conventional oil in western Canada was made at Pembina-Nisku in Alberta in 1977.

'Coming in' party in Edmonton for Leduc No. 1 in 1947. (Provincial Archives of Alberta)

During the 1970s it became evident that conventional oil reserves were declining. This realization, coupled with the new knowledge that bitumen production from the oil sands could be profitable, sparked renewed interest in commercial development of the oil sands — a venture that had been abandoned 30 years earlier when recovery methods proved to be ineffective.

The Great Canadian Oil Sands Limited (now Suncor Inc.) started the first successful commercial plant in 1967. Syncrude Canada Ltd. began operating the second commercial plant in 1978.

Meanwhile, oil companies were looking for other sources of conventional oil and gas, offshore and in the Far North. The oil price increases of the 1970s made development of these remote sources more economically feasible. Several oil and gas discoveries were made offshore in the Beaufort Sea in the 1970s and 1980s; and in 1979, large quantities of oil were found in sandstones in the Hibernia area off the coast of Newfoundland.

These discoveries have supplemented our slowly dwindling reserves of conventional oil and gas. Increasingly, however, Canada's oil industry is looking to the heavy oils of Saskatchewan and Alberta and bitumen of Alberta to supply our future oil needs.

An early bitumen mining operation. The Geological Survey of Canada first studied the oil sands in 1875. Development efforts began in the early 1900s, mostly involving small-scale mining operations producing bitumen for use as road paving material. Even after several decades, Canadians are still discovering the potential of the oil sands. (Provincial Archives of Alberta)

How are oil and gas formed?

The story of Canada's oil and gas deposits began many millions of years ago. For today's oil and gas companies, the key to discovering and tapping the great natural wealth of Canada's oil fields lies in understanding how the oil and gas were formed in the first place.

The science of chemistry provides some of the clues to the origins of oil and gas. Oil and natural gas are hydrocarbons — chemical compounds formed primarily of carbon and hydrogen. Their different properties are due to differences in the number and arrangement of the carbon and hydrogen atoms they contain.

Carbon is heavier than hydrogen, and thus the more carbon atoms in a molecule of fuel, the heavier the fuel. For example, methane (the main component of natural gas) is the simplest hydrocarbon fuel. A molecule of methane consists of four atoms of hydrogen and only one atom of carbon, and at normal temperatures methane is a gas. As the temperature is decreased, its density increases, until at very low temperatures (less than -161°C), it becomes a liquid.

Oil is a mixture of many hydrocarbon fractions, some of which contain more carbon than others. At room temperature, most conventional crude oil is a liquid or, in a few cases, a solid. Because the percentage of high carbon content molecules in crude oil varies, some oils are heavier than others. The heaviest oil is the material known as bitumen found in the oil sands. The heavier

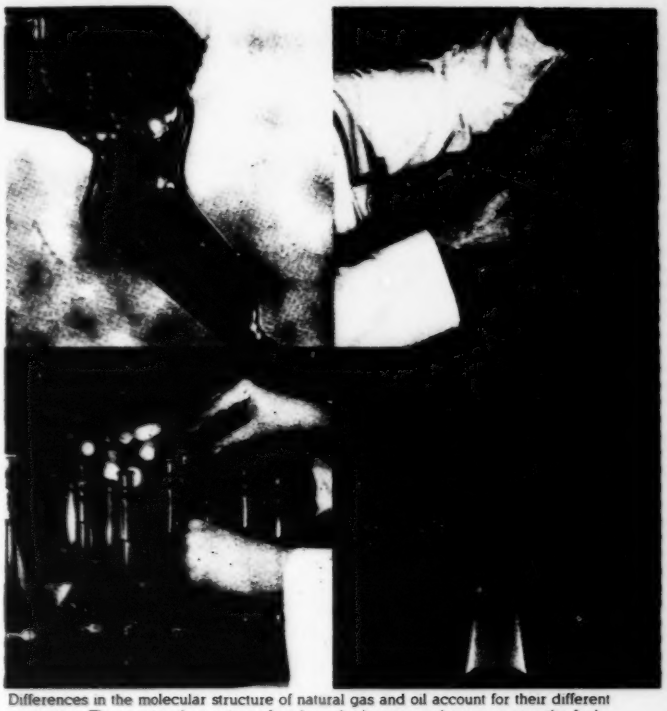
oils are more viscous — that is, they flow less easily at normal temperatures.

The hydrocarbon structure of oil and gas provides clues to their origin, because the cells of living creatures are primarily composed of hydrogen, carbon and oxygen. Although geologists do not yet fully understand how oil and gas were formed, they know that they originated from plants and animals in marine areas.

Much of western Canada has been covered many times by inland seas, which alternately advanced and retreated over time. As marine plants and animals died, their remains settled on the seafloor. Gradually, layers of mud, silt and organic matter built up and were transformed into stratified beds of sedimentary rock. The area covered by the inland seas eventually became what geologists call the Western Sedimentary Basin.

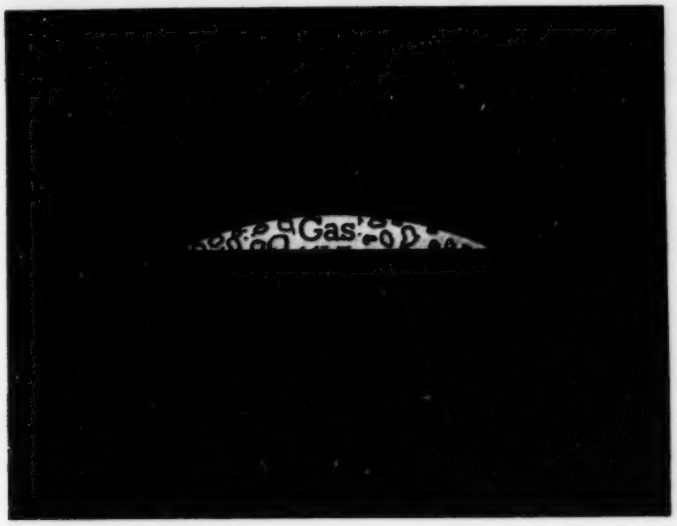
As more time passed, these layers were buried deeper and deeper, compressed by the weight of new layers forming above. Gradually the animal and plant remains were transformed into liquid and gaseous hydrocarbons — crude oil and natural gas.

Because hydrocarbons are lighter than water, they gradually moved upwards through the porous spaces in the sedimentary rock columns. When the oil and gas reached a nonporous layer of rock, they were trapped in reservoirs. It is from these reservoirs that people began extracting oil and gas millions of years later.



Differences in the molecular structure of natural gas and oil account for their different properties. The greater the content of carbon, the heavier and more viscous the fuel. (Imperial Oil Limited, Husky Oil Ltd., Canadian Gas Association)

Geologists believe that fresh water invaded many of Canada's heavy oil deposits, removing soluble light hydrocarbons. The water also provided oxygen that allowed bacteria to attack and consume some of the light fractions, leaving heavy oil or, in the case of the oil sands, bitumen.



Oil and gas trapped in a reservoir

Studying the geology of oil and gas formations helps take some of the guesswork out of finding them. Using sophisticated exploration techniques, Canadian companies are constantly searching for new sources of oil and gas to ensure constant fuel supplies for the future.

The Western Sedimentary Basin stretches across four provinces and into the Yukon and Northwest Territories. Most of Canada's oil and gas is produced in Alberta and Saskatchewan, but there are oil and gas fields in the other western provinces as well. The major oil sands deposits are located in northern Alberta.

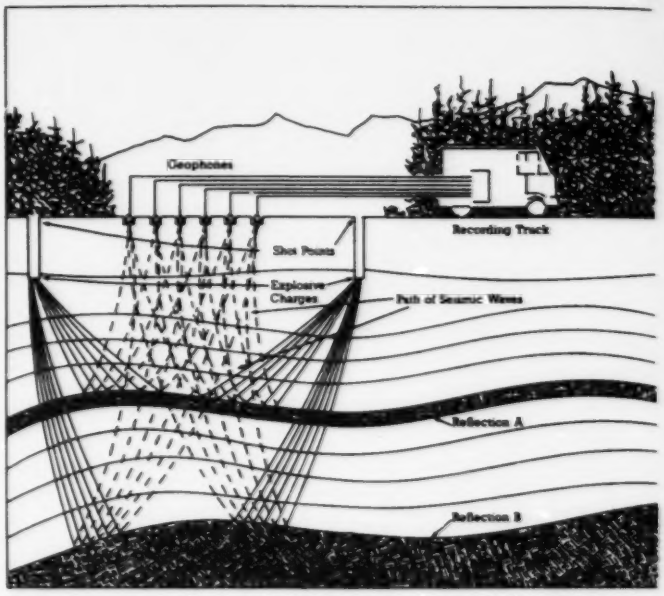
Oil fields ■ Gas fields

Exploration: The first step

Many years of exploration often precede an oil or gas discovery. This search combines the talents of many geological specialists. The art of successful exploration is based on accurate interpretation of the information collected from geological and geophysical data.

The earth's surface often provides field geologists with clues to what lies hidden below. Sometimes the clues are obvious, like actual oil or gas seepages from outcrops of rock. Most clues, however, lie beneath the folded and tilted rocks that might contain traps for oil and gas reservoirs. These are usually thousands of metres below the earth's surface.

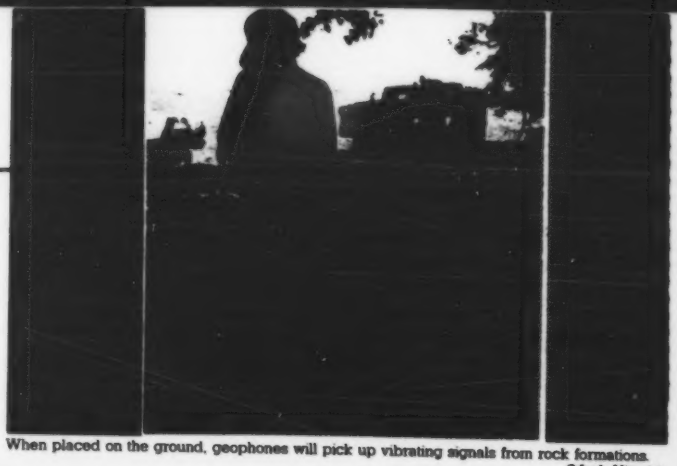
Initially, geological maps help geologists identify promising areas. They may also use magnetometers (which measure variations in the earth's magnetic field) and gravimeters (which measure minute differences in the pull of gravity at the earth's surface), to locate sedimentary rocks. Then, using sophisticated instruments called seismographs, geologists identify potential traps for oil and gas.



The most common type of seismic reflection surveying involves setting off explosive charges in small holes. The explosions create shock waves that are reflected by the subsurface formation, picked up by the geophones and recorded in the recording truck. The time required for the waves to travel down and back from the various formations and the character of these waves are correlated to produce pictures of the underground formations.

Seismographs use the principle of sound wave transmission to create 'pictures' of underground formations. These sound waves are created either by dynamite blasting or by alternative forms of vibration. As the sound waves travel downward and strike various rock formations, they reflect back to the surface. Sensitive instruments called geophones pick up the sonic reflections and send them to a recorder. The recording device records all the data on digital tape, which is then sent to a geophysical processing centre. The time it takes for the waves to travel down and back from the various formations, as well as the intensity of these waves, are correlated to give general characteristics of the underground formations.

The vast amount of data collected from seismographs is entered into highly sophisticated computer programs to produce pictures, or seismograms. By carefully interpreting these seismograms, geologists can identify promising rock formations that may contain oil and gas.



When placed on the ground, geophones will pick up vibrating signals from rock formations. (Mark Vitaris)

Computers are used by geologists to identify promising rock formations. (Imperial Oil Limited)

Recent technological developments are taking seismology a step further. Soon, scientists expect to be able to use seismic tomography to create three-dimensional, detailed images of the continent at several selected locations from British Columbia to Newfoundland.

Before any exploration can take place, however, the right to explore must be acquired. Exploration companies deal with two types of rights: surface rights (rights to work on the surface of the land) and mineral rights (rights to explore for and produce the resources beneath the surface). Some of these rights are owned by individuals, and some by the federal or provincial governments. If surface or mineral rights fall under government control, they are referred to as Crown-owned.

The terms under which a company leases mineral rights from the Crown vary, depending on federal and provincial legislation. Ultimately, a share of the revenues received from oil and gas production is paid by the company to the owner in royalties. For surface rights, the company must acquire a right of entry from the surface owner. This may involve an annual rental fee for use of the land, with an agreement to pay for all damages or inconveniences created by equipment or facilities. Once these agreements are completed, exploration may proceed.

Exploratory wildcat wells are drilled to determine if there are commercial quantities of oil and gas in a given area. (Husky Oil Ltd.)

Once seismic surveys have located oil and gas traps, an exploratory well, known as a wildcat, is drilled. Wildcats are not expected to produce commercial quantities of oil or gas, but provide valuable information on future prospects.

If an exploratory well confirms the presence of commercial quantities of oil or gas, development wells are drilled to define the size of the pool.

Drilling is a carefully calculated operation, done as quickly, efficiently and safely as possible. Lengths of steel pipe known as surface casing are cemented into place to keep the wall of the well bore from caving in and to control the return of the drilling fluid.

Once drilling starts, it continues round the clock. The time it takes to drill a well varies. A shallow well (less than 500 m) may be drilled within three days — possibly sooner if the rock formations are soft. A deep well (greater than 3000 m) may take three to five months to drill if the formations are hard.

Deep or shallow, the progress of wells is constantly monitored. A log or record is kept of the various rock formations encountered throughout the drilling process and tests are conducted to assess the potential hydrocarbon content of the well.

After the hole has been drilled (but sometimes during the drilling), instruments are lowered into the well on an electric cable, which send back information about the formations to the surface. This process, called electric logging, provides information on the thickness, porosity, fluid content, composition and depth of the formations.

Running a drillstem test is another method used to assess the production potential of an oil- or gas-bearing formation. This involves attaching a testing tool to the bottom of the drill pipe and placing it opposite the zone to be tested. Fluids in the zone are allowed to flow up through the drill pipe, enabling the rate and volume of the flow to be measured, as well as fluids to be sampled at the surface.

If the well is judged to be dry and not capable of producing commercial quantities of oil or gas, it is plugged with cement and abandoned. If it appears promising, production casing is installed and production begins.

Production

Getting oil and gas out of the ground is not easy. Sophisticated techniques and equipment must be used to squeeze the most out of every oil and gas deposit, and to recover the more 'difficult' oils: heavy oils and bitumen.

The traditional approach

Oil and gas in a rock formation are under pressure because of the weight of overlying beds of rock and, more important, from columns of water above. When the overlying rock is penetrated, the pressure is released.

Traditionally, oil producers have relied on natural pressures to force oil or gas into the bore hole of a well. Gas flows to the surface; oil can flow but usually needs to be pumped. This initial production is called primary recovery.

These days, many formations are 'stimulated' to increase the flow of oil or gas. Workers may pump acid into the formation to dissolve parts of it so trapped oil and gas can flow into the well bore. Alternatively, they may pump fluid containing sand down into the formation under very high pressure, creating cracks in the rock. When the fluid is sucked back into the well, the sand remains, propping the cracks open and leaving channels for the oil or gas to flow towards the well bore. This process is known as fracturing, or fracing.

Primary recovery techniques have been used for decades to produce oil and gas in western Canada. However, only about one third of the oil in a formation can be recovered in this way. The remainder stays trapped within the pores of the rock.

Furthermore, only about five per cent of heavy oils can be pumped easily to the surface. To recover more oil from existing formations and tap the vast riches of Canada's heavy oil and bitumen deposits, oil companies are turning to more sophisticated secondar and tertiary techniques

Sometimes natural gas is found in a reservoir by itself. It flows to the surface in the same way as oil. Shown here is a 'Christmas tree' — the chokes and valves that make up the wellhead of a producing gas well (Canadian Gas Association)

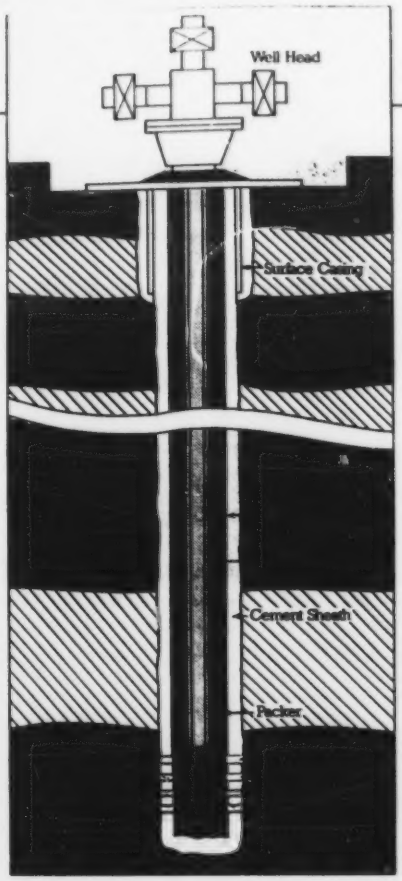
Completing a Well

Once geologists determine that a well can produce commercial quantities of oil or gas, they must follow a complex series of steps to prepare the well for production. This process is called completing the well.

First, production casing is installed. This is tubular steel pipe, which is lowered into the well, lining the length of the well bore. Cement is added, a drillable plug is inserted and pumping is resumed. The pumping pushes the plug down the casing, forcing the cement back up in the space between the casing and the well bore. Once the cement is set, the drilling rig can be moved off the well and a smaller, truck-mounted service rig moved in to finish the well.

Next, production tubing — steel piping that is smaller in diameter than the production casing — is lowered into the casing and suspended from the wellhead. So that fluids will flow into the well bore, engineers perforate the wall of casing and cement with small holes, either by firing tiny steel projectiles, or by a jet of high-pressure gas.

Finally, wellhead equipment, consisting of a series of chokes and valves to control production, replaces the drill or service rig, and pumping begins. The work isn't over, though. Careful monitoring and servicing is needed to maintain production. Hundreds of service rigs operate throughout Canada, completing and repairing wells and helping to keep the oil wells pumping.



Secondary, but not second-rate

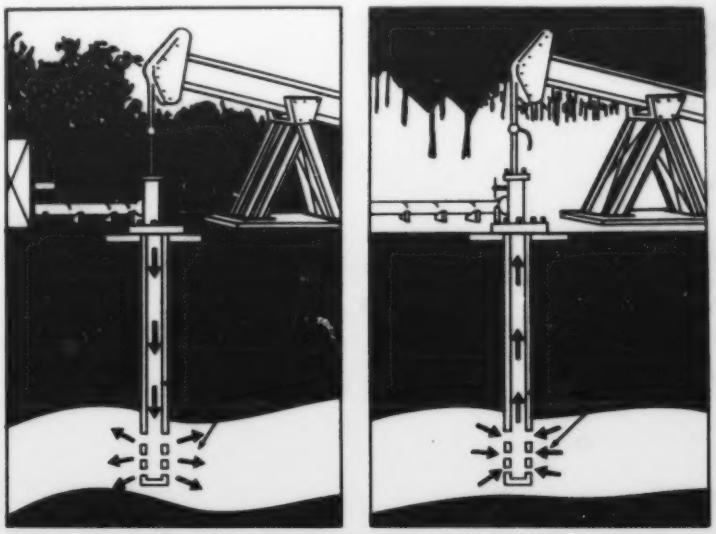
As oil is pumped out, the pressure in the producing formation gradually decreases, and less oil flows into the well bore. To maintain the pressure, many companies use secondary recovery techniques. These involve injecting water or gas, or a mixture of both, down selected neighboring wells to push the oil in the formation towards the well bores.

Secondary techniques can increase the yield of a formation by anywhere from 10 to 50 per cent. About five per cent of Canada's heavy oil deposits can also be recovered by secondary methods. But the real keys to Canada's energy security are the remaining heavy oil deposits and the thick, gooey bitumen locked in the oil sands. To recover these difficult oils, Canadian companies have been developing new approaches — the tertiary or enhanced recovery techniques.

Enhancing recovery of heavy oils

At normal reservoir temperatures, most heavy oils do not flow easily. But if they are heated, heavy oils can be pumped to the surface using conventional equipment.

One way to get heavy oils flowing is to heat them with steam. In a process called steam cycling, or huff and puff, steam is injected into the heavy oil reservoir and the oil brought up through the same well once the steaming

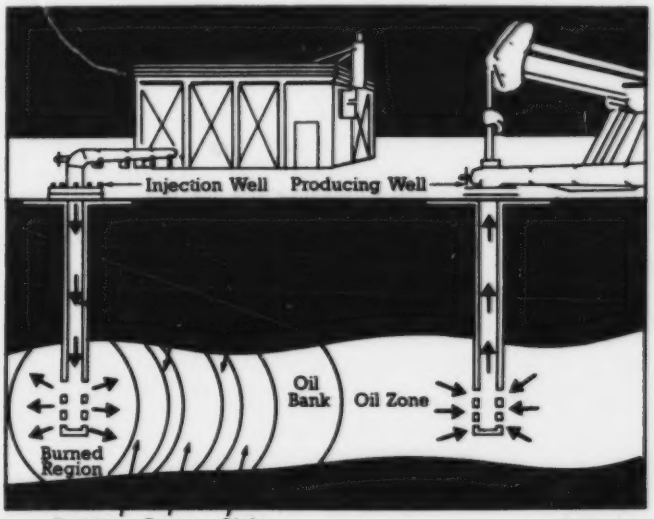


Steam cycle recovery. This is the most commonly used technique to enhance the recovery of heavy oils

process is completed. The steam thins the oil and it is then pumped to the surface.

Another approach, called fireflooding, or in situ combustion, involves setting fire to the part of the oil around the injector well. In this process air, oxygen-enriched air or pure oxygen is injected down into the reservoir and ignited. The fire creates the heat needed to thin the heavy oil, and the combustion gases act like a piston, driving the oil towards the bore of the production well. Continuous injection of air sustains the fire.

The fireflood technique is being used to recover heavy oils in the Lloydminster area. The main advantage of fireflooding is that it can be used on thin reservoirs (less than 6 m thick), which make up many of Canada's heavy oil reservoirs. Steam cycle recovery is not as effective in thin reservoirs because too much heat is lost to surrounding formations that do not contain oil. The more concentrated fireflood technique is more economical for thin formations.



Fireflooding

Tapping the wealth of the oil sands

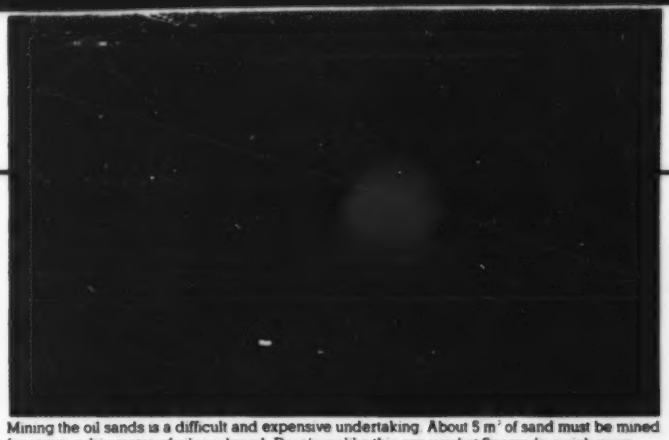
Recovering bitumen from the oil sands is a formidable undertaking. A film of water surrounds each grain of sand and between the grains are tiny droplets of the thick black bitumen. The challenge is to separate the valuable bitumen from the other materials.

There are two approaches to recovering bitumen: surface mining the sand and then separating out the bitumen, or heating the bitumen in the deposit (in situ) to make it flow through the spaces between the sand grains and into a well.

At present, the biggest oil sand mining operations are those of Syncrude and Suncor in the Athabasca oil sands near Fort McMurray, Alberta. Every day, these companies mine hundreds of thousands of tonnes of oil sand and process it to extract bitumen.

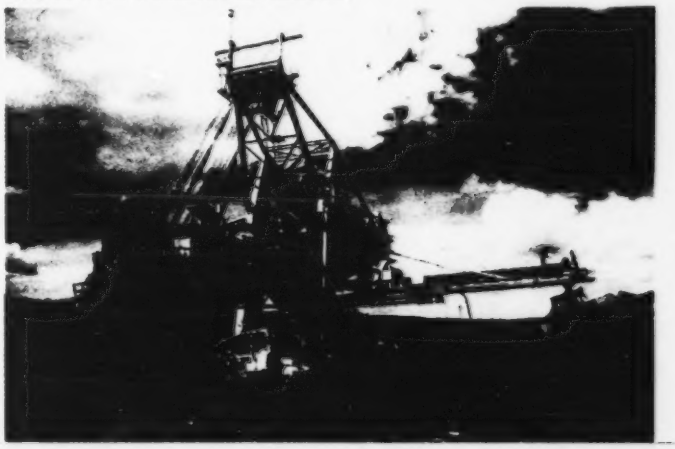
The mining operations are huge. When the Syncrude plant was constructed, it was the largest capital project in Canada's history. The operating costs of both plants are also extremely high, chiefly because vast amounts of overburden must be stripped off the deposits before they can be mined.

Immense technical challenges had to be overcome before oil sand mining became a reality. The abrasive



Mining the oil sands is a difficult and expensive undertaking. About 5 m^3 of sand must be mined for every cubic metre of oil produced. Draglines like this one used at Syncrude weigh more than 6000 t each. (Syncrude Canada Ltd.)

A bucket-wheel excavator at the Suncor plant. It stands as tall as a 10-storey building and can scoop out 60 000 t of oil sand in a day. (Suncor Inc.)



sand, which is sticky in summer and rock-hard in winter, played havoc with equipment. Years of intensive effort went into designing and developing the equipment that now cuts its way through the Athabasca oil sands.

The first step in mining is to strip off the overburden and muskeg covering the deposits. Gigantic draglines and bucket-wheel excavators then scoop out the bitumen ore — the oil sand. High-speed conveyor belts transport the ore to a processing facility, where it is mixed with hot water, steam and chemicals. The bitumen is floated off in separation and flotation units, cleaned and stored for upgrading to synthetic crude oil.

Surface mining is a massive, expensive and environmentally sensitive process. Furthermore, the technique can be used only in parts of the Athabasca area, where the deposits are close enough to the surface. Most of Canada's oil sand deposits are buried several hundred metres underground.

As a result, Canadian companies have been working intensively to develop in situ techniques for bitumen recovery. At the Cold Lake deposits straddling the Alberta-Saskatchewan border, several companies are using the steam cycle recovery technique to recover bitumen from deeply buried oil sands.

The challenge of heavy oil and bitumen production doesn't end with getting them out of the ground, however. Both must be upgraded before they can be refined.

A row of pumpjacks at Cold Lake. Using innovative directional drilling techniques, wells drilled from one location are angled in many different directions. This drastically reduces the amount of land required for wellhead facilities. (Imperial Oil Limited)

Protection of the environment is a priority for the modern oil and gas industries. (Imperial Oil Limited)

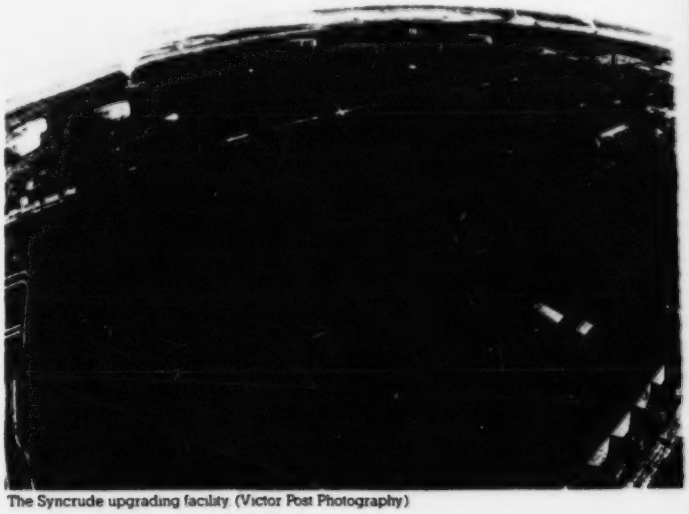
Upgrading

Upgrading is necessary because heavy oils and bitumen contain more carbon-rich fractions than do conventional oils. Because of this, they are heavy, thick and gooey, and cannot be refined until the carbon-hydrogen balance is adjusted.

There are two main ways of upgrading. One is to remove the excess carbon. The other is to add more hydrogen.

Syncrude and Suncor use coking processes to remove excess carbon from bitumen. The bitumen is subjected to intense heat, which causes the large, carbon-rich molecules to break down into smaller hydrocarbon molecules and coke. The lighter hydrocarbons are drawn off as a vapor and separated in a device called a fractionator. These products are then hydrotreated — hydrogen is added to remove sulphur and other impurities and to further increase the hydrogen-to-carbon ratio. The final product, synthetic crude oil, is then ready to be shipped by pipeline to a refinery. The excess carbon solidifies into coke, a coallike byproduct.

Until recently, the use of heavy oils in Canada has been limited because there have been no upgrading facilities for heavy oils. Most of the heavy oil produced in Canada is mixed with lighter hydrocarbons such as condensate to make it flow and then it is shipped through pipelines to



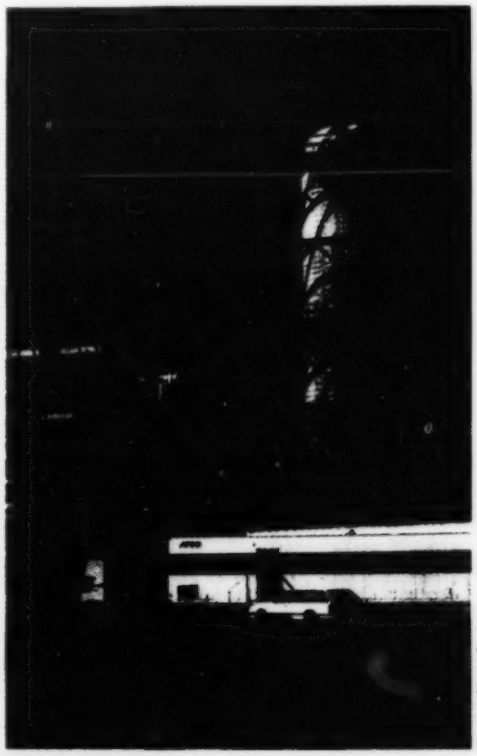
The Syncrude upgrading facility (Victor Post Photography)

markets in the United States. However, NewGrade Energy, a partnership of Federated Co-operatives, the Government of Saskatchewan, and the Government of Canada, has begun work on a heavy oil upgrader adjacent to the Consumers' Co-operative refinery in Regina. This upgrader will process 8000 m^3/day of heavy oil into synthetic light crude oil.

The NewGrade upgrader will upgrade heavy oil by adding hydrogen derived from natural gas. The heavy crude, along with the hydrogen, will be passed under pressure through vessels containing special catalysts. This process will remove sulphur, nitrogen and other contaminants and convert the heavy components to lighter hydrocarbons.

The federal government's Canada Centre for Mineral and Energy Technology (CANMET) has developed a hydrocracking process that upgrades bitumen by adding hydrogen to it under conditions of intense heat and pressure. This process is being tested in a pilot plant in Montreal.

As supplies of conventional oil decline, heavy oils and bitumen will become increasingly important sources of domestic energy. Soon upgrading will be a vital part of the daily business of producing oil.



The NewGrade upgrader The federal government has assisted in the construction of this upgrader by providin loan guarantees. (NewGrade Energy Inc.)

Processing and refining

Crude oil and natural gas cannot be used in their natural state. Natural gas must be processed and crude oil must be refined to produce useful fuels and the raw materials for petrochemical production. Processing and refining are complex and expensive processes requiring sophisticated equipment and techniques.

Processing natural gas

When we speak of natural gas, we usually mean methane, the gas that we burn in our stoves and furnaces. But 'natural gas' as it comes from the well is actually a mixture of gases. In addition to methane, natural gas may contain ethane, propane, butane and carbon dioxide. As well, it contains various solid contaminants and water.

Some natural gas also contains hydrogen sulphide, a poisonous, corrosive gas that smells like rotten eggs. The hydrogen sulphide content of gas varies from deposit to deposit. Gas high in hydrogen sulphide is called sour gas, and gas with no sulphur is called sweet gas.

Raw gas is sent under pressure through pipelines to nearby processing facilities known as gas plants. There are hundreds of these gas processing facilities, many of them in Alberta. At the processing plant, workers remove

Sulphur is an important byproduct of natural gas processing. Canada is one of the world's largest producers and exporters of elemental sulphur, which is used in the manufacturing of fertilizers and for many industrial and chemical processes. (Shell Canada Limited)

Oil from western Canada is piped to refining centres in the western provinces. Ontario and Quebec Refineries in the Atlantic Provinces and in Quebec refine imported oil that is brought in by tanker

water and impurities and separate the other gases such as ethane and propane from the methane. These gases, which are valuable products used as fuels or petrochemical building blocks, may then be liquefied for easy storage and transportation. The methane is shipped to markets through pipelines.

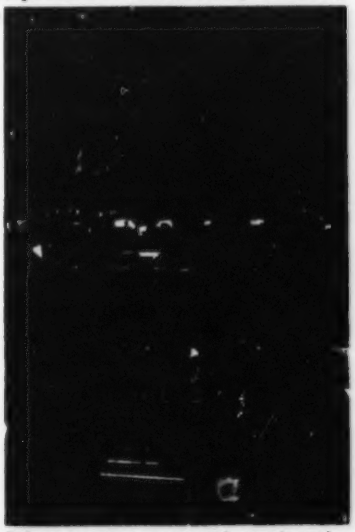
The design of a gas-processing plant is based on the type and volume of natural gas to be processed. The largest, costing several hundred million dollars, processes about 23 million m^3 of gas every day — enough to heat 7000 homes for a year! Any way you look at it, gas processing is big business.

The magic of oil refining

Like raw natural gas, crude oil is not a usable fuel in its natural state. It is a mixture of various hydrocarbons. In addition, crude oil may contain small quantities of contaminants, including sulphur, various metals, salt, water and suspended grit. These impurities are removed during refining, and the various hydrocarbons are separated and recombined to form useful products.

The first step in refining is fractional distillation. A liquid will become a gas, or vice-versa, at a specific temperature, known as the boiling point. Fractional distillation makes use of this fact to separate the various components of crude oil on the basis of differences in their boiling points.

The crude oil is heated and passed through tall distillation columns. The temperature in the column is highest at the bottom and lowest at the top. The liquid component, made up of the heavier compounds, flows down the column. As the temperature increases, some of the hydrocarbons that have lower boiling points vaporize to form gases. The gases flow up the column through a series of perforated metal trays. As each hydrocarbon in the gas mixture cools to its boiling point, it turns back into a liquid. These liquids are drawn out of the columns at specific temperature levels known as cut points. The lightest gases do not liquefy, and are drawn off at the top of the column, while the heaviest hydrocarbons do not vaporize and are drawn off as a liquid at the bottom.



Refining processes are extremely complex and refineries are large and capital-intensive industrial plants. Unlike natural gas processing plants, which are located near the producing fields, oil refineries are located as close as possible to the markets for their products, to minimize the distances and costs involved in distributing these products. Crude oil is transported through pipelines from the field to the refinery. (Imperial Oil Limited)

Distillation is only the first step in refining. The proportion of different compounds such as diesel fuel, jet fuel and gasoline produced by distillation does not match the demand for specific products. The heaviest fractions cannot be used as fuel, and distillation does not produce enough gasoline, one of the products that is most in demand. Therefore, refiners use complex chemical processes to further treat the products of distillation in order to make more of the fuels we need most.

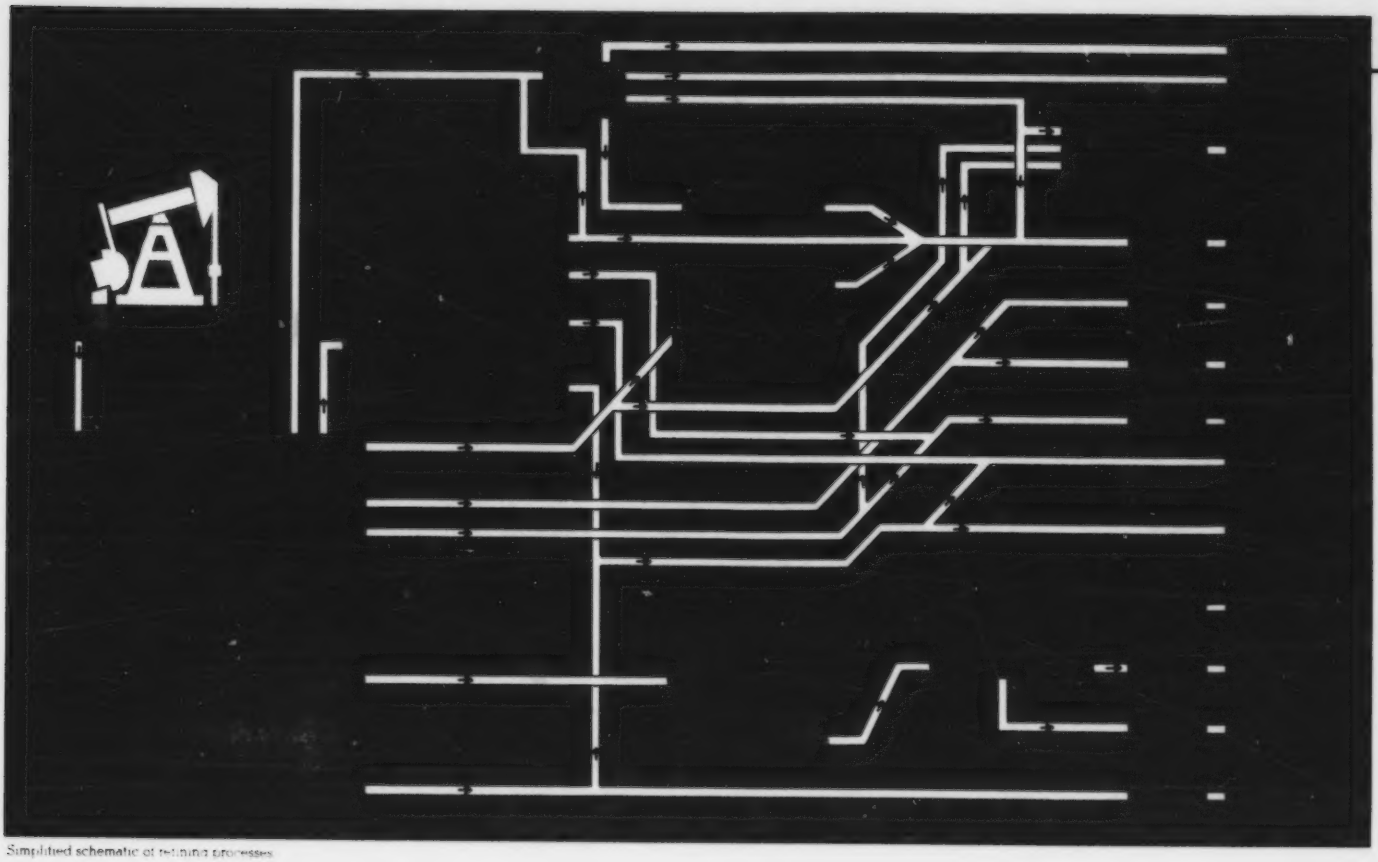
These processes include cracking, reforming and alkylation. Cracking uses heat and pressure to break the heaviest fractions into lighter fractions, particularly gasoline. Reforming involves changing the form or shape of gasoline molecules to produce a higher quality gasoline. The process of alkylation combines the lightest gases to form heavier hydrocarbons useful in the blending of gasoline.

All these processes are designed to ensure that the refinery produces the quantity and quality of products consumers want, with no waste. This is not easy. The quality of crude oil varies, and distillation of different grades of crude produces different amounts of the various fractions. Consequently, refining is a chemical juggling job requiring great skill to produce a balanced output of products.

In addition, the refiner must take into account seasonal variations in product requirements. Demand for gasoline increases during the summer, when many Canadians take to the road on vacations. During the winter, they use more heating oil. Changes in vehicle fuel requirements — such as the switch from leaded to unleaded gasoline — also affect product specifications.

Distillation columns (Shell Canada Limited)

The task of balancing all the factors involved in refining is extremely complex. It has not been getting any easier, either. As many Canadians have switched from oil to natural gas and other fuels for home heating and industrial uses, refiners have had to adjust their processes to produce less heavy fuel oil and more gasoline and diesel fuel.



Simplified schematic of refining processes

Synthetic crude oil has advantages in this respect, because it yields large volumes in the boiling range of gasoline, diesel and jet fuels when refined. However, synthetic oil presents a whole new set of challenges to the refiner. Although it looks like conventional light oil, synthetic oil is quite different chemically. These differences affect the quality of some refined products, particularly diesel fuel and jet fuel.

Refiners can get around this problem by producing gasoline from the synthetic oil and refining conventional oil to produce the diesel and other products they need to meet market demands. However, only a small amount of synthetic oil can be used in this way — less than 25 per cent of the refinery input. Special processes are needed to produce a balanced output of products from synthetic oil alone.

To meet this new need, oil companies have been bringing new refineries on stream — refineries that are designed specifically to handle synthetic crude. Constantly adapting to changing supplies and demands, Canadian refineries are meeting the challenge of providing consumers with high-quality products.

Four refineries in Canada — the Shell Canada Limited refinery in Scotford, Alberta, the Petro-Canada refinery in Edmonton, the ESSO refinery in Edmonton, and the Suncor refinery in Sarnia — can refine large quantities of synthetic oil. Shown here is the Scotford refinery, which began operations in 1984. It is designed to refine only synthetic oil, and can handle about 8000 m^3 a day. An addition to the Petro-Canada refinery can handle 6400 m^3 a day of synthetic oil; the main refinery refines about 12 800 m^3 a day of conventional crude. (Shell Canada Limited)

From Plastics to Polyester: The Many Products of Canada's Petrochemical Industry

Oil and gas are not just important sources of fuel. They also provide the basis for Canada's large petrochemical industry. This industry, which began during World War II to produce synthetic rubber for tires, accounts for about five per cent of Canada's total oil consumption and about 20 per cent of our gas consumption.

Petrochemical plants use a variety of processes to alter the molecular structure of hydrocarbons such as naphtha, gas, oil and refinery gases from oil refineries, as well as ethane, propane and butane from the processing of natural gas. These raw materials are used to produce primary petrochemicals, which are then used to make other products. For example, naphtha or ethane is used to produce the primary petrochemical ethylene, which is then used to produce secondary petrochemicals, such as polyethylene plastics or styrene.

Petrochemicals form the basis for everything from synthetic fabrics such as nylon and polyester to plastics, paints, detergents, inks, cosmetics, pharmaceuticals and industrial and agricultural chemicals. Every time you wear permanent press clothing, drink out of a styrofoam coffee cup, wash dishes or read a book (including this one), you are using products from Canada's oil and gas industry.

'Petrochemical Valley' in Sarnia, Ontario, home of many of Canada's largest petrochemical plants (Grafiks, Sarnia, Ontario)

Pipelines: Linking producers and markets

Crude oil and natural gas must be transported from the fields where they are produced to the places where they are consumed. Pipelines provide this vital link.

In a country as large as Canada, where significant oil and gas fields are located hundreds and even thousands of kilometres from major populated and industrial areas, pipelines are the most efficient and economical way of supplying consumer and industrial demands. Most of Canada's oil and gas fields are in western Canada; however, the more populated consumer markets in eastern Canada rely heavily on western supplies.

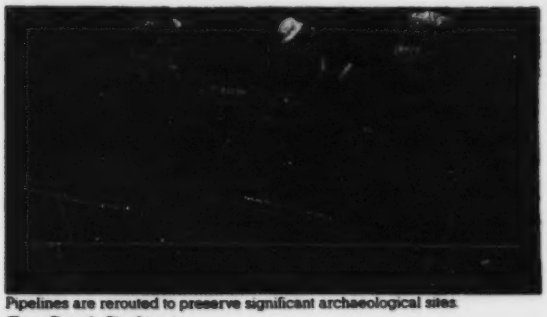
The Interprovincial pipeline for crude oil and the TransCanada pipeline for natural gas span the Prairie Provinces and northern United States to reach markets in eastern Canada. An estimated 3105 km long, the Interprovincial is one of the longest crude oil pipeline systems in the world. There are an estimated 200 000 km of oil and gas pipelines in Canada.

Pipelines carry crude oil to refineries for processing. In western Canada, small pipelines gather crude oil from thousands of producing wells, and then larger systems move it to refineries throughout the country. Refined products such as diesel fuel and gasoline are often sent by pipelines from refineries to distribution terminals before reaching the consumer.

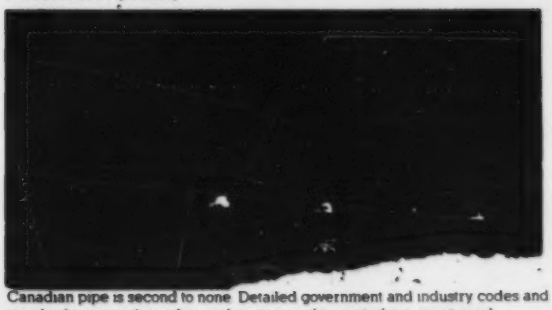
Natural gas, on the other hand, is processed closer to where it is produced, and then moves from the plants directly to pipelines. Gathering lines in western Canada link up to large transmission systems which carry the gas to various distribution systems. The distributors' pipeline networks then deliver the gas directly to homes, businesses and industries.

Pipeline companies take great care to minimize the environmental impact of pipelines. Once a pipeline has been installed, the earth above it is restored and revegetated. (TransCanada PipeLines)

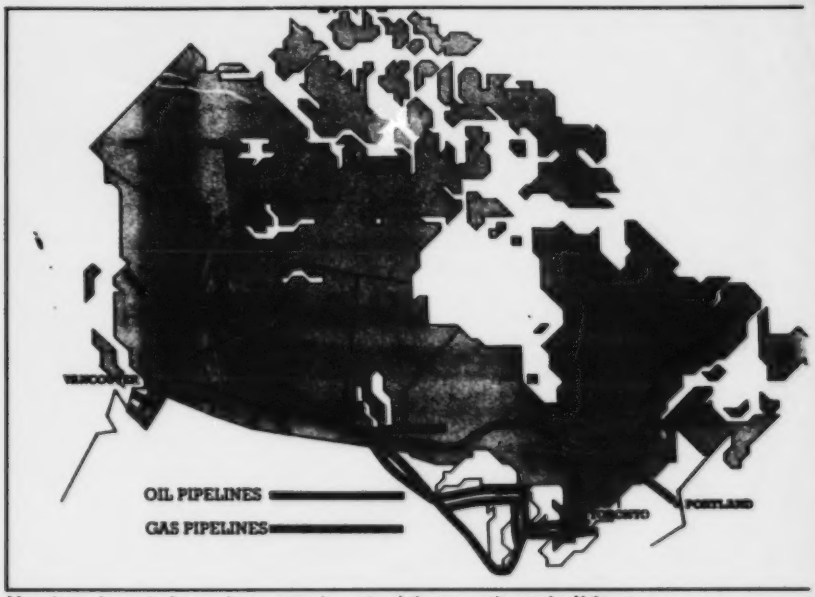
As new energy sources are found and developed in western Canada, the Arctic, and offshore along Canada's east coast, pipelines continue to serve as the safe, silent and hidden transporters of oil and natural gas.



Pipelines are rerouted to preserve significant archaeological sites. (TransCanada PipeLines)



Canadian pipe is second to none. Detailed government and industry codes and standards ensure that safety and proper quality control are maintained. (TransCanada PipeLines)



More than a dozen pipelines make up a complex network that covers thousands of kilometres.

The end of the pipe

Distribution and marketing are the final links in the petroleum industry chain that begins hundreds of metres below the ground and ends in your home. In a country as large as Canada, an efficient distribution system is essential.

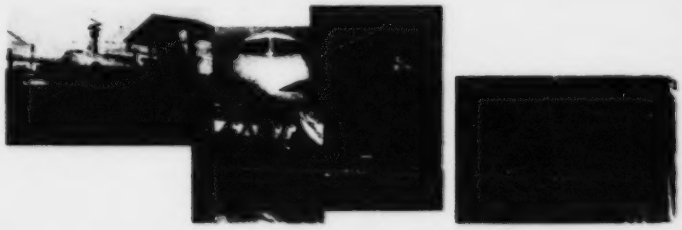
The distribution system that delivers oil products to the marketplace begins with tanker trucks, railway tank cars and product pipelines. These take the products from refineries to distribution points known as bulk stations. Here, the products are stored for subsequent delivery to industrial plants, service stations and homes. Natural gas, on the other hand, is distributed through local distribution pipeline networks, which carry the natural gas from the main transmission pipelines right to the end consumers.

The market for oil and gas is varied and changeable. The transportation industry accounts for the lion's share of demand for oil because Canadians rely so heavily on gasoline and diesel fuels.

Until the late 1970s residential and industrial heating was the other major source of demand for oil. Since 1979 the use of oil for heating has declined dramatically as industries and individual Canadians have taken steps to conserve energy by switching off oil in favor of natural gas and electricity.

Homes and industries use natural gas mainly as a heating fuel. It is also used for cooking and in the production of chemicals and fertilizers, and is becoming increasingly popular as an inexpensive vehicle fuel for commercial and industrial fleets.

Exports are another important use for Canadian oil and gas. We both export and import oil; historically it has been more economical and convenient to import oil for use in the Atlantic Provinces and parts of Quebec than to extend the distribution network from western Canada to those provinces. However, since 1983, Canada has been a net exporter of crude oil, particularly heavy oils. Natural gas exports to the United States account for more than one quarter of our total production. These exports play a significant role in maintaining Canada's balance of trade.



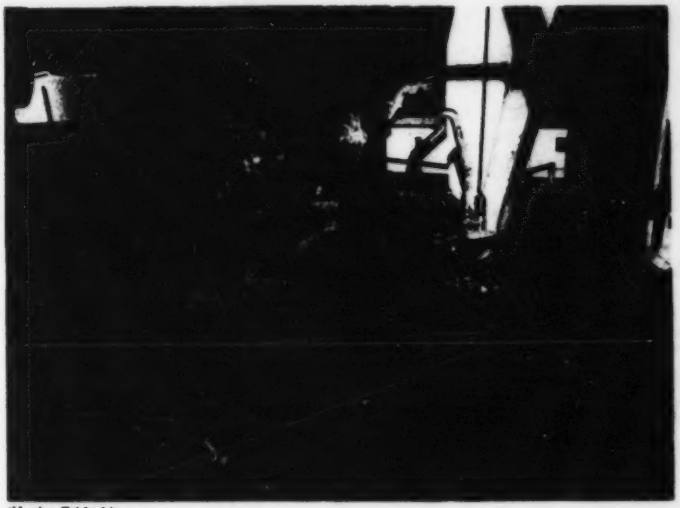
Service stations requiring gasoline receive their supplies from tanker trucks coming from bulk stations. Airlines receive large volumes of jet fuel from railway tank cars, trucks and sometimes by pipeline direct from the refinery. Diesel fuel for trains may be supplied direct from refineries or bulk stations. Heavy bunker fuel oil is brought to ships by barges operating from marine terminals or refineries. (CP Rail, Shell Canada Limited, Husky Oil Ltd., Imperial Oil Limited.)

The challenge of the future

When James Miller Williams drilled that first oil well in 1858, he could not have foreseen how Canada's oil and gas industry would grow. Today oil and gas from western Canada are mainstays of our energy supply and our economy.

Canada's future depends on assured supplies of energy, including oil and gas. Supplies of conventional light crude oil are gradually being depleted, but we have large reserves of natural gas, heavy oil and bitumen. For the oil and gas industry, the challenge is to exploit these reserves economically to meet the country's energy needs.

Among other things, this means developing more and better methods of producing and upgrading heavy oils, improving in situ techniques for bitumen production, and adapting refineries to handle increasing quantities of synthetic crude oil. It means developing new sources of oil and gas offshore and in the northern frontier. Above all, it means continuing the tradition of innovation and excellence that has always characterized the Canadian oil and gas industry.



(Husky Oil Ltd.)